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(54) Medical or dental hardening compositions

Erhärtende Zusammensetzungen zur Verwendung in der Medizin oder Zahnheilkunde

Compositions durcissables pour usage médical ou dentaire

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(56) References cited:
EP-A- 0 241 277
WO-A-91/12212
FR-A- 2 485 504
GB-A- 2 199 027

- **DATABASE WPIL Week 8504, Derwent Publications Ltd., London, GB; AN 85-021799**

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Description

Field of the invention

This invention relates to medical or dental hardening compositions and, more particularly, to medical or dental hardening compositions, which are inorganic materials or composite materials made of inorganic materials and organic materials, and used as a bone cement or dental cement to fill or to fit prosthesis in defects or voids produced in bones or teeth by illness or external reasons. The medical or dental hardening compositions allow the treated part to form a new bone or tooth, and later become monolithic with the osseous tissue or dental tissue. This invention further pertains to hardening compositions for filling bones and teeth, which act as X-ray opacity material thus use allowing easy and accurate postoperative observation.

Background of the invention

Defects or voids are caused in bones or teeth by traffic accidents and ablation of osteoncus in the fields of surgery and orthopaedic surgery, and by periodontoclasia, alveoloclasia, odontectomy and cutting-off of dental caries in the field of dental surgery. Various materials including one's own bone, polymers, metals, ceramics etc. have been used to fill such defects and voids, as well as for the dental prosthesis. Among them, one's own bone is excellent since it has high bone forming capacity and causes little rejection. However, as one's own bone must be taken from the one's normal bone tissue, the operation causes great pain and in many cases not enough tissue can be secured. Thus, recently, hydroxyapatite has been replacing the use of one's own bone tissue. Hydroxyapatite can be obtained by synthesized or by sintered animal bones, and removing organic components, and it is known to have excellent biocompatibility. However, when hydroxyapatite in powder or granular form is used as a filling material, such problems as the tendency for it to run-off with blood or body fluids, or transuded as a foreign body even after suturing have been pointed out.

Sintered bodies of hydroxyapatite are exemplified in FR-A-2485504.

For cementing and fitting a prosthesis in the hard tissue bone-cement has been used. As the bone-cement, so called medical polymers based on PMMA (polymethyl methacrylate) have been used in most cases, however, these materials show insufficient biocompatibility and have such problems as the pain in the affected part caused by the reaction heat generated during the hardening reaction, or the harmfulness of the nonreached monomer to the living body.

Meanwhile, a dental cement material has been used not only as a coalescent for prosthesis, but also as a filling material or a lining material, and various dental cement materials have been developed as restortion materials in the field of dental surgery. Among them, glass ionomer cement, as shown in British Patent Number 1316129. made of glass powder produced by melting alumina and silica at a high temperature using a flux such as fluoride, and a hardening liquid made of a copolymer of acrylic acid and an unsaturated carboxylic acid, exhibits great crushing resistance after hardening, relatively good adhesion to tooth, and minimum harmfulness to dental pulp. However, it has a problem of insufficient biocompatibility.

In this context, a new dental cement made of such inorganic components that constitute the hard tissue have recently been drawing attention, and cements based on calcium phosphate or apatite type crystalline powder have been under development as well. The main components of these materials are bone analogues and have excellent biocompatibility, but the reactivity of the crystalline powder with an organic hardening liquid is very bad, since the components that react with the hardening liquid are very limited. Compositions for filling bones and teeth comprising α-tricalcium phosphate and a liquid component, have been disclosed in US Patent No. 4,677,140, however, since the crushing resistance of the cement is very low, they cannot be employed for practical use.

Those dental cement materials developed so far have different merits and demerits respectively, and need to be chosen according to the particular purpose, however, the commonly required characteristics of a dental cement material include sufficient hardening characteristics and biocompatibility, and a material satisfying both of them has been desired.

In addition, no materials having both biocompatibility and X-ray opacity have been found for the medical or dental uses. It is needless to say that biocompatibility is very important for a biomaterial, but, in the case of an artificial material to be implanted in a body in some way, it is also important to know the condition of the artificial material when it is implanted, or to follow its change with time correctly. Thus, X-ray opacity also becomes an important property. In order to render X-ray opacity, a metal oxide or a metal salt of such a metal as strontium, barium or lanthanum have been typically blended as X-ray opacity material with the base material. However, those X-ray opacity components do not have biocompatibility, and have high solubility in a living body, or have problems in causing harmful effects including allergies. In view of the above-described problems, a material whose X-ray opacity component per se has biocompatibility and which can remain stable in a living body has also been strongly desired.

Calcium phosphate glass ceramics are known (e.g.from GB-A-2199027) but one cannot give the necessary heat treatment in situ when used as an implant.

Biocompatible materials comprising x-ray opaque glass ceramic powders in a polymer matrix have been proposed in EP-A-0241277 and WO-A-91/12212.

Summary of the invention

In order to solve the above-described technical problems, the present invention is aimed at, as is clear from the above description, providing medical or dental hardening compositions having sufficient hardening capacity and strength as well as excellent biocompatibility which are required for prosthesis and filling materials.

Another object of the present invention is to provide medical or dental hardening compositions having X-ray opacity as well.

Brief description of the drawings

Fig. 1 is an X-ray diffraction pattern of calcium phosphate type devitrification glass-ceramics powder obtained in Example 2.

Fig. 2 is an X-ray diffraction pattern of strontium phosphate type devitrification glass-ceramics powder obtained in Example 4.

Fig. 3 is an X-ray diffraction pattern of calcium strontium phosphate type devitrification glass-ceramics powder obtained in Example 5.

General description of the invention

The medical or dental hardening compositions of the present invention comprise calcium phosphate type devitrification glass-ceramics powder containing apatite and/or calcium phosphate ceramics, and a liquid component. Such compositions provide materials with good hardening and biocompatability properties. The strontium phosphate type materials also provide x-ray opacity. The invention is defined in claims 1-6.

An exemplary explanation of the present invention will be given as follows.

The calcium phosphate type devitrification glass-ceramics powder of the present invention must contain apatite and/or calcium phosphate ceramics. These ceramics are the main components of bone, and accelerate the formation of a new bone. Calcium phosphate type devitrification glass-ceramics is not produced by simply adding and mixing these ceramics with glass: it must be devitrification glass with crystallized and stabilized ceramics dispersed therein. The ceramics phase is indispensable for attaining biocompatibility. The coexistence of glass in the ceramics is also an essential condition. This glass is indispensable as it provides excellent hardening capacity, and only so called devitrification glass-ceramics where the ceramics and glass are coexist, can provide hardening compositions showing both good biocompatibility and good hardening capacity. To generate these ceramics, appropriate amounts of calcium and phosphate salts, which become the main components, must be added to the raw materials. Particularly, since a feature of the present invention resides in the point that the devitrification glass-ceramics is produced by quickly cooling melted glass product and crystallizing a portion thereof without re-heating or gradually cooling melted glass to be crystallized, the selection and the blending of the raw materials for devitrification are very important. To produce so called crystallized glass in a normal process either produced glass is re-heated or melted glass is gradually cooled, however, the calcium phosphate type devitrification glass-ceramics of the present invention is produced by quenching the glass in a molten condition to devitrify it, thus, highly active devitrification glass-ceramics can be obtained. The term "highly activity" means that reaction components can be easily provided to the various liquids to be described later. so that hardening compositions of good physical properties can thus be obtained. These "physical properties" include hardening time, strength of the hardened mass and stability to dissolution.

An exemplary raw material chemical composition of calcium phosphate type devitrification glass-ceramics powder of the present invention is shown as follows:

CaO :	20 - 60 % by weight
P_2O_5 :	5 - 32 % by weight
SiO_2 :	15 - 30 % by weight
Al_2O_3 :	3 - 37 % by weight
F_2 :	1 - 10 % by weight
MgO :	0 - 2 % by weight

The reasons for limiting the chemical composition of the calcium phosphate type devitrification glass-ceramics powder will be described as follows. If the content of CaO is below 20 % by weight, the calcium phosphate type ceramics mainly containing hydroxyapatite will not form, resulting in poor biocompatibility, and conversely a content of over 60

% will result in a decrease in the glass component in the total. Namely, means the component involving the hardening reaction is decreased, resulting in inferior hardening characteristics.

If the content of P_2O_5 is below 5 % by weight, calcium phosphate type ceramics will not be formed, there will be no affinity to an organism, and if it is over 32 % by weight, the resulting chemical resistance may be inferior with corrosion thereof in the organism occurring undesirably.

If the content of SiO_2 is below 15 % by weight, the glass component rate in the total is decreased, and the clarity is lowered, and if it is over 30 % by weight, the rate of the calcium phosphate ceramics in the glass-ceramics powder becomes relatively small, and low biocompatibility.

If the content of Al_2O_3 is below 3 % by weight, glass strength is lowered, and if it is over 37 % by weight, biocompatibility will decrease in the same manner as the case of SiO_2.

F_2 is effective as a flux, and if it is applied in the dental field, addition in the amount of 1 - 10 % by weight will show a slow fluorine releasing effect, but if it is over 10 % by weight, the original mechanical strength and the chemical resistance of the devitrification glass-ceramics itself may be lowered.

More than one component chosen from the group consisting of MgO, Na_2O and B_2O_3 may be added to control the melting temperature of the glass or to control the amount of ceramics to be generated. However, if it is added in a large quantity, it may excessively control the crystallization of the calcium phosphate type ceramics, and result in lowering of biocompatibility. Accordingly, the amount of such component to be added is not more than 2 % by weight.

The strontium phosphate type devitrification glass-ceramics powder or calcium strontium phosphate type devitrification glass-ceramics powder of the present invention must contain strontium-apatite and/or strontium phopsphate ceramics or stontium substituted apatite. These ceramics are very analogous to the main components of bone, and accelerate osteoconduction. This is not produced simply by adding and mixing those ceramics with glass; but this must be so-called devitrification glass-ceramics where the crystallized and stabilized ceramics is dispersed in the glass. The ceramics is indispensable for rendering the biocompatibility and X-ray opacity. The coexistence of the glass in the ceramics is also an essential condition. This glass is indispensable for providing excellent hardening capacity, and so-called devitrification glass-ceramics in which the ceramic and the glass co-exist provide good hardening compositions showing good biocompatibility, X-ray opacity and hardening capacity. In order to generate these ceramics, the raw materials must contain appropriate amounts of strontium salt, or calcium salt and phosphate salt compound which become the main components. Particularly, since a feature of the present invention resides in the point that the devitrification glass-ceramics is produced by quickly cooling the melted glass product and crystallizing a portion thereof without re-heating or gradually cooling melted glass to be crystallized, the selection and the blending of the raw materials for the devitrification are very important. To produce so called crystallized glass in a normal process, either produced glass is re-heated or melted glass is gradually cooled, however, the devitrification glass-ceramics of the present invention is produced by quenching cooling the glass in a molten condition to devitrificate it, thus, highly active devitrification glass-ceramics can be obtained. The term "highly activity" mean that reaction components can be easily provided to the various liquids to be described later, so that hardening compositions of good physical properties can thus be obtained. These "physical properties" include hardening time, strength of the hardened mass and stability to dissolution.

An exemplary raw material chemical composition of strontium phosphate type devitrification glass-ceramics or calcium strontium phosphate type devitrification glass-ceramics powder of the present invention is shown as follows:

SrO :	3 - 55 % by weight
CaO :	0 - 40 % by weight
P_2O_5 :	5 - 32 % by weight
SiO_2 :	15 - 30 % by weight
Al_2O_3 :	3 - 37 % by weight
F_2 :	1 - 10 % by weight
MgO :	0 - 2 % by weight

SrO is indispensable as a component to render X-ray opacity, however, in the present invention, so-called X-ray opacity component is not simply added and mixed in order to render the X-ray opacity. Those materials shown low bioactivity, and have problems such as high dissolution capacity in organisms and harmfulness to cause allergies. A feature of the present invention is that the strontium, which is effective as a component to render the X-ray opacity, is not contained in the form of strontium oxide (SrO) but forms, in the generated devitrified glass, strontium apatite $[Sr_{10}(PO_4)_6(OH)_2]$, strontium phosphate or strontium substituted apatite $[Sr_xCa_{10-x}(PO_4)_6(OH)_2]$ having a structure analogous to the main components of bone or tooth.

The reasons for limiting the raw material composition of the strontium phosphate type devitrification glass-ceramics powder or calcium strontium phosphate type devitrification glass-ceramics powder are described as follows. If the content of SrO is below 3 % by weight, it is not sufficient to render X-ray opacity, and if it is over 55 % by weight, the glass component rate in the total is decreased, thus the component involving the hardening reaction is decreased, and the

resulting hardening characteristics may be inferior. The appropriate content of CaO is between 0 and 40 % by weight, and when it is 0 % by weight, pure strontium-apatite or strontium phosphate ceramics is generated in the devitrified glass. When CaO is blended, strontium substituted apatite is generated. This is a solid solution and a apatite type ceramics that continuously changes structure depending on the ratio of the amounts of SrO and CaO will be generated. The blending ratio thereof can be changed freely depending on the desired crystal phase, or the desired X-ray opacity, but their total is preferably not more than 60 % by weight. That is because, if the amount exceeds 60 % by weight, the glass component rate in the total is decreased, thus the component involving the hardening reaction is decreased resulting in inferior hardening characteristics. Though the generated ceramics vary depending on the CaO content, all of them have a structure that is very analogous to the hard tissue, and show very high biocompatibility.

If the content of P_2O_5 is below 5 % by weight, strontium phosphate ceramics or calcium strontium phosphate ceramics will not be formed, there will be no affinity to an organism, and if it is over 32 % by weight, the resulting chemical resistance may be inferior, with corrosion thereof in the organism occurring undesirably.

If the content of SiO_2 is below 15 % by weight, the glass component rate in the total is decreased to lower the clarity, and if it is over 30 % by weight, the rate of the strontium phosphate ceramics or calcium strontium phosphate ceramics in the glass powder becomes relatively small, and biocompatibility is be lowered.

As for Al_2O_3, F_2, MgO, Na_2O, and B_2O_3, the above-mentioned description given for the calcium phosphate type devitrification glass-ceramics can be applied in the same way.

As a liquid component, one solution chosen from the group consisting of physiological saline solution, a water soluble polymer solution, an inorganic acid aqueous solution, an organic acid aqueous solution, an aqueous solution of a polymer of an unsaturated carboxylic acid and a mixture of these, is preferably employed. For example, for use as a dental cement, since strength must be displayed in a short time, an aqueous solution of a polymer of an unsaturated carboxylic acid having a concentration of 20 - 80 % is preferably used. More preferably, an aqueous solution having a concentration of 40 - 60 % to which an inorganic acid or an organic acid having the concentration of 20 % or less is added to control the hardening characteristics is employed.

For the use as a filling material for a defect in bones or a root canal, a physiological saline solution is recommended since it is free from the stimulus of .in acid or an alkali, however, it is effective to add a suitable amount of a water soluble polymer such as CMC (sodium carboxymethyl cellulose) or polyethylene glycol, etc. to physiogical saline solution in order to render fluidity and viscosity.

The devitrification glass-ceramics of the present invention may contain small amounts of alkaline earth metal silicate ceramics such as wollastonite ($CaO \cdot SiO_2$), diopside ($MgO \cdot CaO \cdot 2SiO_2$), and forsterite ($2MgO \cdot SiO_2$) in addition to hydroxyapatite, calcium phosphate ceramics, strontium-apatite, strontium phosphate ceramics, and strontium substituted apatite.

Examples

Some examples of this invention will be described in further details as follows. It is to be understood that the following examples are simply illustrative of the invention, and other arrangements may be devised by those skilled in the art which will embody the principles of the invention and fall within the spirit and scope thereof.

Example 1:

Glass raw materials were prepared to have a composition of CaO: 43.1 % by weight, P_2O_5: 18.6 % by weight, SiO_2: 20.9 % by weight, Al_2O_3: 11.9 % by weight, MgO: 0.5 % by weight, and F_2: 5.0 % by weight. This was melted for 2 hours at 1600°C, then quenched in water to produce devitrification glass. Under X-ray diffractometry hydroxyapatite, tricalcium phosphate ceramics and glass were recognized.

The obtained devitrification glass-ceramics powder was then finely into a powder having an average particle size of 10 μ m, a liquid component made of physiological saline solution and 1 % CMC was added thereto at a ratio of 2 (powder) to 1 (liquid) by weight, and the setting time was found to be 6 hours.

This was next filled in medullary cavities drilled in two spots of a thigh bone of a three-week old Wistar rat, then cut out after three months, prepared into a polished thin section in a conventional manner, and observed by microscope. Newly formed bones was found to surround and penetrate the glass-ceramics powder, and the bonds were firm.

In place of the calcium pohosphate type devitrification glass-ceramics having an average particle size of 10 μm, a mixture of aluminosilicate glass powder having an average particle size of 10 μm and hydroxyapatite crystal powder having an average particle size of 10 μm (a mixing ratio of 1:1 by weight) was filled in medullary cavities drilled at two spots of a thigh bone of a three-week old Wistar rat in the same way as in Example 1, and cut out after three months, prepared into a polished thin section in a conventional manner, then observed by microscope to find one layer of newly formed bone around the filled part.

Example 2:

Glass raw materials were prepared to have the composition of CaO: 32.0 % by weight, P_2O_3; 9.0 % by weight, SiO_2: 24.5 % by weight, Al_2O_3: 29.0 % by weight, MgO : 0.5 % by weight, and F_2: 5.0 % by weight. This was melted for 2 hours at 1600°C, then quenched in air to produce devitrification glass. This was finely ground into a powder having an average particle size of 3 μm by a pot mill. X-ray diffractometry showed that a glass and ceramics co-existed, that the ceramics was hydroxyapatite, and that the ratio of the glass to the hydroxyapatite was 7:3. The results are shown in the Fig 1.

A liquid component made of 40 % by weight of polycarboxylic acid having an average molecular weight of about 15000, which was produced from itaconic acid (40 % by weight) and acrylic acid (60 % by weight), 10 % by weight of tartaric acid, and 50 % by weight of water was added to the obtained devitrification glass-ceramics powder at the weight ratio of 1.2 (powder) to 1 (liquid), and the resulting product was then tested in accordance with "JIS T-6602". The obtained cement showed a hardening time of 4 minutes, a compression strength after 24 hours of 1460 kg/cm^2, and a dissolution rate in 24 hours of 0.09 %. When the liquid was mixed with the powder at the weight ratio of 1.8 (powder) to 1 (liquid), the resulting cement showed a hardening time of 4 minutes 30 seconds, and a compression strength after 24 hours of 1810 kg/cm^2.

Example 3:

Glass raw materials were prepared to have the compositions shown in the following Table I, and melted at 1400 - 1650 °C, then quenched in water to produce devitrification glass-ceramics (Samples No. 1 - 7). They were pulverized by a pot mill to have an average particle size of 2 - 5 μm. 1.0 part by weight of a liquid component made of 40 % by weight of polyacrylic acid, 10 % by weight of tartaric acid and 50 % by weight water was added to 1.6 parts by weight of the devitrification glass-components powder, then ground, and the properties of the obtained hardened mass were investigated. The list contains the results identification of the crystal phase identification by X-ray diffractometry, hardening time, and the compression strength after 24 hours. Products obtained by formulating the glass raw materials of samples No. 8 - 11 followed by known nucleated glass production process, and hydroxyapatite powder (Sample No. 12) were examined on the same points as the comparative examples. An especially remarkable point was that the products of the present invention showed a compression strength of 1150 - 1600 kg/cm^2, while the comparative examples, samples No. 8 - 12 showed low values between 50 - 400 kg/cm^2.

Table I

Sample No.	Chemical composition (% by weight)						Crystal phase (1)	Hardening time (2)	Compression strength (kg/cm^2)
	CaO	P_2O_5	SiO_2	Al_2O_3	MgO	F_2			
1	49.8	24.6	16.3	3.8	0.5	5.0	H	2min	1150
2	45.4	20.7	20.1	8.3	0.5	5.0	H	2.5min	1210
3	40.8	16.5	21.8	15.4	0.5	5.0	H	3.5min	1280
4	36.2	12.2	23.4	22.7	0.5	5.0	H	4min	1360
5	32.0	9.0	24.5	29.0	0.5	5.0	H	4min	1460
6	31.6	7.9	25.0	30.0	0.5	5.0	H	4.5min	1600
7	28.0	7.0	25.0	30.0	0.5	9.5	H	4min	1320
8	15.0	2.5	71.8	10.0	0.5	0.2	G	10sec	57
9	27.0	5.0	31.0	30.0	2.0	5.0	A/H	10min	50
10	20.0	5.0	38.0	30.0	2.0	5.0	A	15min	63
11	14.9	6.9	35.0	30.4	1.7	11.1	A/H	1hr	115
12	Hydroxyapatite powder						H	9min	370

(1) H: Hydroxyapatite, A: Anorthite, G: Glass

(2) The ratio of powder to liquid = 1.2:1

(3) Samples No. 1 - 7 : products of the present invention, and Samples No. 8 - 12: comparative examples.

Example 4:

Glass raw materials were prepared to have a composition of SrO: 36.2 % by weight. P_2O_5 : 12.2 % by weight, SiO_2 : 23.4 % by weight, Al_2O_3 : 22.7 % by weight, MgO : 0.5 % by weight, and F_2 : 5.0 % by weight. This was melted for 2 hours at 1600°C, then quenched in water to produce devitrification glass-ceramics. Under X-ray diffractometry strontium-apatite, tristrontium phosphate and glass were recognized. The results are shown in the Fig 2.

The obtained devitification glass-ceramics powder was then finely ground into a powder having an average particle size of 10 μm, a liquid componet made of physiological saline solution and 1 % CMC was added thereto it at a ratio 2 (powder) to 1 (liquid) by weight, and the setting time was found to be 8 hours. The X-ray opacity was equivalent to that of a pure aluminum plate of 6 mm.

This was next filled in medullary cavities drilled it two spots of a thigh bone of a mongrel adult dog and X-ray radiographic inspection was carried out. The filling substance showed up clearly taken. After 3 months, this was cut out and prepared into a polished thin section in a conventional manner, then observed by microscope to find that newly formed bone surrounded and penetrated the glass-ceramics powder, and that the bonds were firm.

In place of the strontium phosphate type devitrification glass-ceramics having an average particle size of 10 μm, a mixture of aluminosilicate glass powder having an average particle size of 10 μm and hydroxyapatite powder having an average particle size of 10 μm (a mixing ratio of 1:1 by weight) was filled in medullary cavities drilled at two spots of a thigh bone of a mongrel adult dog in the same way as in Example 4, and checked by X-ray, but no clear difference between the surrounding part and the filling material was recognized. It was cut out after three months, prepared into a polished thin section in a conventional manner, then observed by microscope to find one layer of new bone around the filling material.

Example 5:

Glass raw materials were prepared to have the composition of SrO: 27.8 % by weight, CaO: 12.0 % by weight, P_2O_3: 7.0 % by weight, SiO_2: 22.0 % by weight, Al_2O_3: 26.4 % by weight, MgO: 0.5 % by weight, and F_2: 4.4 % by weight. This was melted for 2 hours at 1600°C, then quenched in air to produce devitrification glass-ceramics. It was finely ground into a powder having an average particle size of 3 μ m by a pot mill. X-ray diffractometry carried out on the obtained devitrification glass-ceramics powder showed coexisting glass and ceramics, that the ceramics was strontium substituted apatite, and that the ratio of the glass to the ceramics was 7:3. The results are shown in Fig 3.

A liquid component made of 40 % by weight of polycarboxylic acid having an average molecular weight of about 15000, which was produced from itaconic acid (40 % by weight) and acrylic acid (60 % by weight,), 10 % by weight of tartaric acid, and 50 % by weight of water was added to the obtained devitrification glass-ceramics powder at the weight ratio of 1.2 (powder) to 1 (liquid), the resulting product was then tested in accordance with "JIS T-6602". The obtained cement showed a hardening time of 6 minutes, a compression strength after 24 hours of 1240 kg/cm^2, and a dissolution rate in 24 hours of 0.28 %. When the liquid was mixed with the powder at the weight ratio of 1.8 (powder) to 1 (liquid), the resulting cement showed a hardening time of 5 minutes and a compression strength after 24 hours of 1630 kg/cm^2. The X-ray opacity of the product was equivalent to that of a pure aluminum plate of 5 mm.

Example 6:

Glass raw materials were prepared to have the compositions shown in the following Table II, and melted at 1400 - 1650°C , then quenched in water to produce devitrification glass-ceramics (Samples No. 1 - 3). They were pulverized by a pot mill to have an average particle size of 2 - 5 μ m. 1.0 part by weight of a liquid component made of 40 % by weight of polyacrylic acid, 10 % by weight of tartaric acid and 50 % by weight of water was added to 1.6 parts by weight of the devitrification glass-ceramics powder, then ground, and the properties of the obtained cements were investigated. The list contains the results of the crystal phase identification by X-ray diffractometry, hardening time, the compression strength after 24 hours, and X-ray opacity. Products obtained by formulating the glass raw materials of samples No. 4 - 6 followed by known nucleated glass production process, and hydroxyapatite crystal powder (sample No. 8) were examined on the same points as comparative examples. An especially remarkable point was that the products of the present invention showed a compression strength of 1040 - 1680 kg/cm^2, while the comparative examples, samples No. 4 - 8 showed low values between 50 - 400 kg/cm^2.

Table II

Sample No.	Chemical composition (% by weight)							Crystal phase (1)	Hardening time (2)	Compression strength (kg/cm^2)	X-ray opacity (3)
	SrO	CaO	P_2O_5	SiO_2	Al_2O_3	MgO	F_2				
1	25.0	6.6	7.9	25.0	30.0	0.5	5.0	S	7min	1040	5
2	11.7	19.9	7.9	25.0	30.0	0.5	5.0	S	5min	1390	3
3	5.0	26.6	7.9	25.0	30.0	0.5	5.0	S	3min	1680	2
4	0	15.0	2.5	71.8	10.0	0.5	0.2	G	10sec	57	1
5	0	27.0	5.0	31.0	30.0	2.0	5.0	H/A	10min	50	2
6	0	20.0	5.0	38.0	30.0	2.0	5.0	A	15min	63	1
7	0	14.9	6.9	35.0	30.4	1.7	11.0	H/A	1hr	115	1
8	0	Hydroxyapatite powder						H	9min	370	1

(1) S: Strontium substituted apatite, H: Hydroxyapatite, A: Anorthite, G: Glass

(2) The ratio of powder to liquid = 1.6 : 1

(3) X-ray opacity was evaluated by X-ray radiographic inspection using a dental roentgen device and pure aluminium plates having 10 different thicknesses varying from 1 mm to 10mm and a sample having a thickness of 1 mm. The X-ray opacity of the sample is shown in terms of the thickness of the aluminum plate having equivalent transmissivity. Conditions and Device: SUNEXRAY D-65-S, Tube Voltage: 65Kvp, Tube current : 10 mA, Distance : 300 mm, Irradiation time : 0.7 sec, Film : Kodak NF-55

(4) Samples No. 1 - 3 : products of the present invention, Samples No. 4 - 8 : comparative examples.

As it is also clear from the above-described results, it can be understood that the medical or dental hardening compositions satisfying the requirements specified in the present invention show good hardening characteristics and good biocompatibility.

As it is clear from the above description, new medical or dental hardening compositions showing good hardening capacity, sufficient compression strength and good biocompatibility can be provided in accordance with the present invention. By the use of strontium phosphate type devitrification glass-ceramics powder containing strontium-apatite or strontium phosphate apatite or calcium strontium phosphate type devitrification glass-ceramics powder containing strontium substituted apatite, the resulting medical or dental hardening compositions show good X-ray opacity as well.

Claims

1. A medical or dental hardening composition comprising as components:-

   i) a glass ceramics powder formed by quenching from a melt without subsequent heat treatment and comprising:-

      a) a calcium phosphate type glass-ceramics powder containing both glass and apatite and/or calcium phosphate ceramics;
      or

      b) a strontium phosphate type glass-ceramics powder containing both glass and strontium-apatite and/or strontium phosphate ceramics;
      or

      c) a calcium strontium phosphate type glass-ceramics powder containing both glass and strontium substituted apatite.

   and,

   ii) a liquid component.

2. A medical or dental hardening composition as claimed in Claim 1 in which the glass ceramics powder is produced by melting chemical components comprising of CaO and/or SrO; P_2O_5; Al_2O_3; SiO_2; and F_2 and optionally one or more components selected from the group MgO; Na_2O and B_2O_3. and by quenching the melt without subsequent heat treatment.

3. A medical or dental composition as claimed in Claim 1 or Claim 2 in which the liquid component is selected from the group comprising:-

   physiological saline solution;
   a water soluble polymer solution;
   an inorganic acid aqueous solution;
   an organic acid aqueous solution;
   an aqueous solution of a polymer of an unsaturated carboxylic acid;

   or is a mixture of two or more of said group.

4. A medical or dental hardening composition as claimed in any of Claims 1 to 3 in which the glass ceramics powder is a calcium phosphate type glass-ceramics powder containing both glass and apatite and/or calcium phosphate ceramics and has the composition (in weight percent):-

CaO	20 - 60
P_2O_5	5 - 32
SiO_2	15 - 30
Al_2O_3	3 - 37
F_2	1 - 10
MgO	0 - 2

5. A medical or dental hardening composition as claimed in any of Claims 1 to 3 in which the glass ceramics powder is a strontium phosphate type glass-ceramics powder containing both glass and strontium-apatite and/or strontium phosphate ceramics or a calcium strontium phosphate type glass-ceramics powder containing both glass and strontium substituted apatite and has the composition (in weight percent):-

SrO	3 - 55
CaO	0 - 40
P_2O_5	5 - 32
SiO_2	15 - 30
Al_2O_3	3 - 37
F_2	1 - 10
MgO	0 - 2

6. A method of forming a medical or dental hardening composition as claimed in any preceding claim comprising mixing a glass ceramics powder formed by quenching from a melt without subsequent heat treatment and comprising:-

   a) a calcium phosphate type glass-ceramics powder containing both glass and apatite and/or calcium phosphate ceramics;

   b) a strontium phosphate type glass-ceramics powder containing both glass and strontium-apatite and/or strontium phosphate ceramics;
   or

   c) a calcium strontium phosphate type glass-ceramics powder containing both glass and strontium substituted apatite.

   with a liquid component.

Patentansprüche

1. Medizinische und dentale Härtungsmittel-Zusammensetzung, die folgende Komponenten aufweist:

i) ein Glaskeramik-Pulver, das durch Quenchen aus einer Schmelze ohne nachfolgende Wärmebehandlung gebildet wird, und das folgendes aufweist:

a) ein Glaskeramik-Pulver der Calciumphosphat-Art, das sowohl Glas wie auch Apatit und/oder Calciumphosphat-Keramik enthält;
oder

b) ein Glaskeramik-Pulver der Strontiumphosphat-Art, das sowohl Glas wie auch Strontium-Apatit und/oder Strontiumphosphat-Keramik enthält;
oder

c) ein Glaskeramik-Pulver der Calcium-Strontiumphosphat-Art, das sowohl Glas wie auch Strontium-substituiertes Apatit enthält.

und

ii) eine flüssige Komponente.

2. Medizinische oder dentale Härtungsmitte-Zusammensetzung nach Anspruch 1, bei der das Glaskeramik-Pulver durch Schmelzen chemischer Komponenten, die aus CaO und/oder SrO; $P_2 0_5$; Al_2O_3; SiO_2; und F_2 und gegebenenfalls einer oder mehrerer Komponenten bestehen, die ausgewählt sind aus der Gruppe MgO; Na_2O und B_2O_3, und durch Quenchen der Schmelze ohne nachfolgende Wärmebehandlung hergestellt wird.

3. Medizinische oder dentale Zusammensetzung nach Anspruch 1 oder Anspruch 2, bei der die flüssige Komponente ausgewählt ist aus der Gruppe, die folgendes aufweist:

physiologische Kochsalzlösung;
eine wasserlösliche Polymerlösung;
eine wässrige Lösung einer anorganischen Säure;
eine wässrige Lösung einer organischen Säure;
eine wässrige Lösung eines Polymers einer ungesättigten Carbonsäure;

oder ein Gemisch aus zwei oder mehreren der Komponenten der Gruppe ist.

4. Medizinische oder dentale Härtungsmittel-Zusammensetzung nach einem der Ansprüche 1 bis 3, bei der das Glaskeramik-Pulver ein Glaskeramik-Pulver der Calcium-phosphat-Art ist, das sowohl Glas wie auch Apatit und/oder Calciumphosphat-Keramik enthält, und das die Zusammensetzung (in Gewichtsprozent) hat:

CaO	20 - 60
P_2O_5	5 - 32
SiO_2	15 - 30
Al_2O_3	3 - 37
F_2	1 - 10
MgO	0 - 2

5. Medizinische oder dentale Härtungsmittel-Zusammensetzung nach einem der Ansprüche 1 bis 3, bei der das Glaskeramik-Pulver ein Glaskeramik-Pulver der Strontiumphosphat-Art ist, das sowohl Glas wie auch Strontium-Apatit und/oder Strontiumphosphat-Keramik oder ein Glaskeramik-Pulver der Calcium-Strontiumphosphat-Art enthält, das sowohl Glas als auch Strontium-substituiertes Apatit enthält, und das die Zusammensetzung (in Gewichtsprozent) hat:

SrO	3 - 55
CaO	0 - 40
P_2O_5	5 - 32
SiO_2	15 - 30
Al_2O_3	3 - 37
F_2	1 - 10
MgO	0 - 2

6. Verfahren zur Bildung einer medizinischen oder dentalen Härtungsmittel-Zusammensetzung nach einem der vorhergehenden Ansprüche, das das Vermischen eines Glaskeramik-Pulvers aufweist, das durch Quenchen aus einer Schmelze ohne nachfolgende Wärmebehandlung gebildet wird, und das folgendes aufweist:

a) ein Glaskeramik-Pulver der Calciumphosphat-Art, das sowohl Glas wie auch Apatit und/oder Calciumphosphat-Keramik enthält;

b) ein Glaskeramik-Pulver der Strontiumphosphat-Art, das sowohl Glas wie auch Strontium-Apatit und/oder Strontiumphosphat-Keramik enthält;
oder

c) ein Glaskeramik-Pulver der Calcium-Strontiumphosphat-Art, das sowohl Glas wie auch Strontiumsubstituiertes Apatit enthält.

mit einer flüssigen Komponente.

Revendications

1. Composition de durcissement médicale ou dentaire comprenant en tant que composants :

i) une poudre de céramique de verre formée par trempe d'un mélange fondu sans traitement thermique subséquent et comprenant :

a) une poudre de céramique-verre du type phosphate de calcium contenant à la fois du verre et de l'apatite et/ou une céramique de phosphate de calcium ;
ou
b) une poudre de céramique-verre du type phosphate de strontium contenant à la fois du verre et de l'apatite-strontium et/ou une céramique phosphate de strontium ;
ou
c) une poudre de céramique-verre du type phosphate de strontium-calcium contenant à la fois du verre et de l'apatite substituée par du strontium,

et

ii) un composant liquide.

2. Composition de durcissement médicale ou dentaire selon la revendication 1 dans laquelle la poudre de céramique-verre est produite par fusion de composants chimiques comprenant CaO et/ou SrO ; P_2O_5 ; Al_2O_3 ; SiO_2 ; et F_2 et optionnellement un ou plus composants choisis dans le groupe de MgO ; Na_2O et B_2O_3 et par trempe du mélange fondu sans traitement thermique subséquent.

3. Composition médicale ou dentaire selon la revendication 1 ou la revendication 2 dans laquelle le composant liquide est choisi dans le groupe comprenant :

une solution saline physiologique ;
une solution de polymère soluble dans l'eau ;
une solution aqueuse d'un acide inorganique ;
une solution aqueuse d'un acide organique ;
une solution aqueuse d'un polymère d'un acide carboxylique insaturé ;

ou est un mélange de deux ou plus dudit groupe.

4. Composition de durcissement médicale ou dentaire selon l'une quelconque des revendications 1 à 3 dans laquelle la poudre de céramique-verre est une poudre de céramique-verre du type phosphate de calcium contenant à la fois du verre et de l'apatite et/ou une céramique de phosphate de calcium et a la composition (en % poids) :

CaO	20 - 60
P_2O_3	5 - 32
SiO_2	15 - 30

Al_2O_3	3 - 37
F_2	1 - 10
MgO	0 - 2

5. Composition de durcissement médicale ou dentaire selon l'une quelconque des revendications 1 à 3 dans laquelle la poudre de céramique-verre est une poudre de céramique-verre du type phosphate de strontium contenant à la fois du verre et de l'apatite-strontium et/ou une céramique de phosphate de strontium ou une poudre de céramique-verre du type phosphate de calcium-strontium contenant à la fois du verre et de l'apatite substituée par du strontium et a la composition (en % poids) :

SrO	3 - 55
CaO	0 - 40
P_2O_3	5 - 32
SiO_2	15 - 30
Al_2O_3	3 - 37
F_2	1 - 10
MgO	0 - 2

6. Méthode de formation d'une composition de durcissement dentaire ou médicale selon l'une quelconque des revendications précédentes comprenant un mélange de poudre de céramique-verre formé par trempe à partir d'un mélange fondu sans traitement thermique subséquent et comprenant :

a) une poudre de céramique-verre du type phosphate de calcium contenant à la fois du verre et de l'apatite et/ou une céramique de phosphate de calcium ;
b) une poudre de céramique-verre du type phosphate de strontium contenant à la fois du verre et de l'apatite-strontium et/ou une céramique phosphate de strontium ;
ou
c) une poudre de céramique-verre du type phosphate de calcium-strontium contenant à la fois du verre et de l'apatite substituée par du strontium,

avec un composant liquide.

FIG. 1

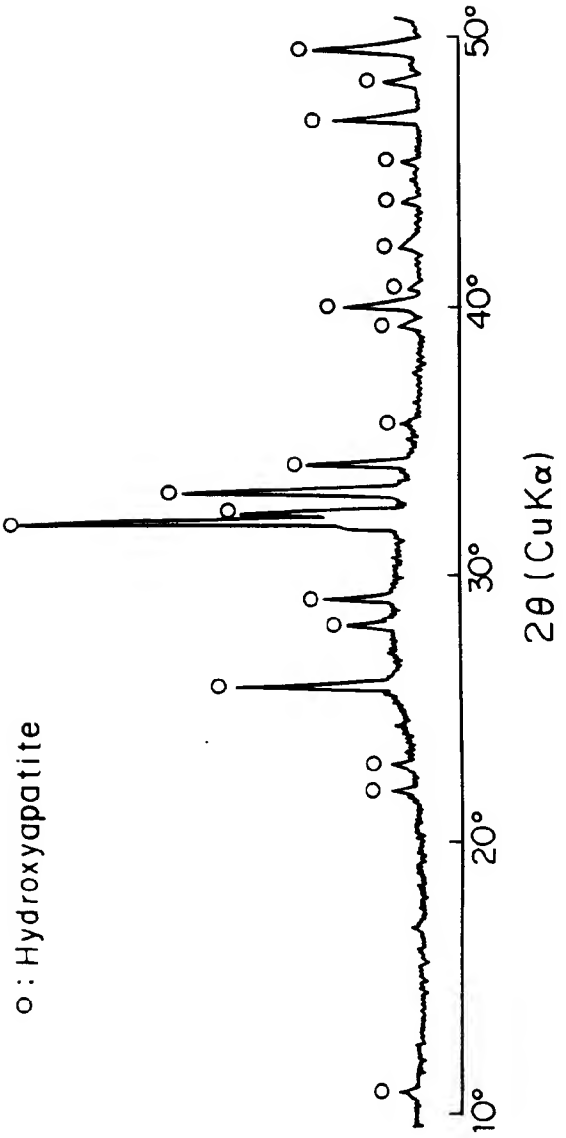


FIG. 2

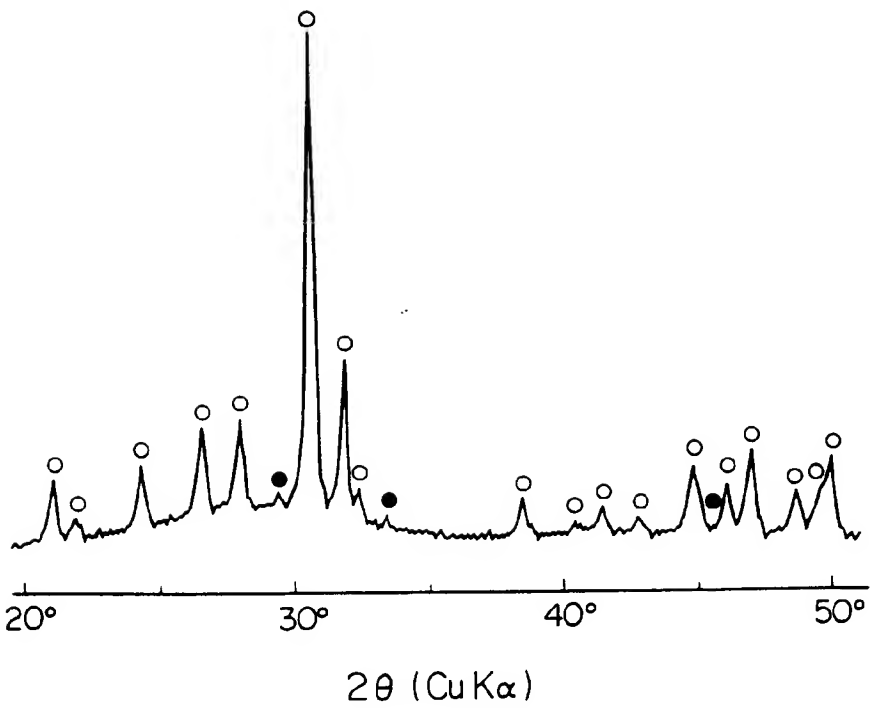
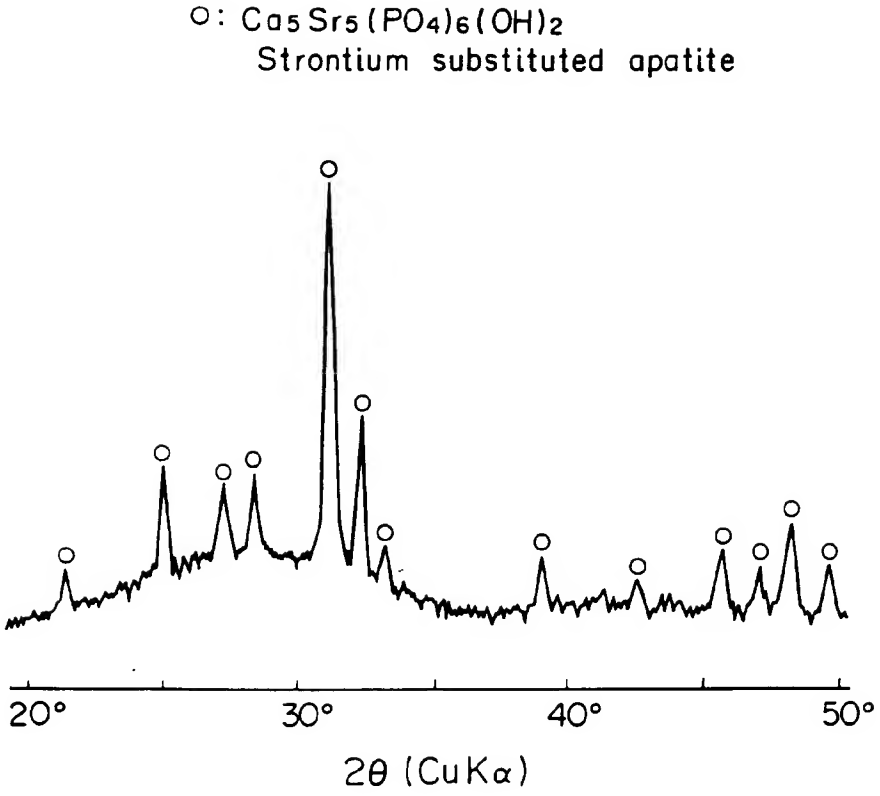

○ : Sr10(PO4)6(OH)2
Strontium-apatite
● : Sr3(PO4)2
Tristrontium-phosphate
20°
30°
40°
50°
2θ (CuKα)

FIG. 3


○: $Ca_5Sr_5(PO_4)_6(OH)_2$
Strontium substituted apatite
20°
30°
40°
50°
2θ (CuKα)